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TYPES AND CHARACTERISTICS OF UNIVERSITY STUDENTS' SCIENCE IDENTITY

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Abstract. *Understanding the science identity of university students who have completed the national science curriculum is essential, as it provides insight into how formal education shapes their relationship with science. This study examines the forms of science identity among university students, moving beyond insider-oriented definitions that hinge solely on proximity to scientists. In this study, science identity is defined as the self-perception formed through the integration of one's perceptions of the self, society, and science in scientific contexts. To investigate this construct, we employed Q methodology. From 335 statements generated through literature review and interviews, 42 were selected as the Q sample. Forty university students then completed Q-sorts, resulting in the identification of four distinct science identity types. The science acceptance type recognized the importance of science yet perceived distance from it. The science use type viewed science as a practical tool, with limited concern for ethical or social implications. The science-loving type valued science intrinsically, enjoying inquiry but showing weaker engagement with responsibility. The science responsibility type emphasized addressing environmental and societal challenges through science. By moving beyond an insider-centred view, this study highlights diverse identity forms and their implications for science education.*

Keywords: *competent outsider, science education, science identity, scientific literacy, Q methodology*

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Introduction

In today's rapidly changing societies, a central challenge of science education lies in equipping learners with the capacity to connect science to their own lives and social realities. This goal is articulated as the cultivation of scientific literacy (AAAS, 1989; NRC, 2012; MOE, 2022). Scientific literacy is more closely related to the competence of a "competent outsider" than to that of an "insider" with specialized scientific knowledge (Feinstein, 2011). This means that science does not remain in the epistemological dimension of "knowing" but becomes ontologically embedded in an individual's "life" (Park, 2016). In other words, a scientifically literate person connects science with life, taking a scientific approach to personal and societal issues and engaging in science-related practices.

As the ability to connect science with oneself is emphasized, the concept of science identity has gained increasing attention. Identity is created and reconstructed in relation to society and is understood as a dynamic entity that encompasses social and cultural contexts and practices (Lave & Wenger, 1991; Lemke, 2000). Accordingly, science identity can be defined as a comprehensive self-awareness of "who one is, what one can do, what one wants to do, and what one wants to be" in a scientific context (Aschbacher et al., 2010). From this perspective, science education extends beyond simply learning about the outside world to the process of forming the self and establishing a way of being within a community.

Research has consistently shown that a strong science identity plays a critical role in students' persistence and participation in science (Carlone & Johnson, 2007; Chen & Wei, 2022). However, much of this work has defined science identity narrowly, focusing on the extent to which one identifies as a scientist—an insider-oriented framing that risks obscuring the diverse forms such identity can take (Hazari et al., 2010; Robnett et al., 2018). More recent studies have suggested that the development of science identity through formal schooling is better understood not as the attainment of an insider ideal—being proficient in science, feeling close to it, and liking it—but as

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the cultivation of one's distinctive scientific "taste" (Anderhag, 2017). This perspective assumes the diversity of science identities and highlights the need for science education to acknowledge and support the unique identities individuals form, rather than prescribing a single, standardized model of what constitutes a desirable science identity. Moreover, a number of studies have emphasized culturally responsive and multifaceted approaches to science identity, underscoring the importance of subjective meaning-making and the sociocultural embedding of science in everyday life (Vincent-Ruz & Schunn, 2018; Weinstein, 2008; Irwin, 2002).

While previous studies have characterized science identity through dimensions such as competence, performance, recognition, and interest (Carlone & Johnson, 2007; Hazari et al., 2010), with recognition by others frequently cited as the most influential factor (Tytler & Ferguson, 2023), this framework tends to emphasize external validation and individual attributes while offering only limited attention to the broader sociocultural and epistemic contexts in which identities are negotiated. To address this limitation, we foreground perception as a foundational mechanism, arguing that it mediates how individuals interpret and position themselves in relation to self, society, and science. From this perspective, science identity develops through the interpretive and evaluative processes enabled by perception (Brickhouse & Potter, 2001).

In light of this, rather than defining science identity solely in terms of alignment with scientists or the scientific community, this study reconceptualizes it through three interrelated perceptual dimensions—perceptions of self, society, and science. This approach provides a broader and more inclusive framework that reflects the diverse ways individuals engage with science beyond the pursuit of a scientific career. To operationalize this expanded view, we draw on Hewitt's (2000) tripartite model of identity, which conceptualizes personal, social, and situated dimensions as co-constitutive aspects of selfhood. In the context of science education, this framework allows us to map science identity across three epistemic foci: (1) self, encompassing perceptions of one's science-related emotions and abilities as well as external resources and evaluations (e.g., support, opportunities, feedback); (2) society, including perceptions of the characteristics, norms, and culture of the community to which one belongs, one's position within it, and awareness of societal issues and challenges; and (3) science, referring to one's internalized understanding of what science is, and to the perceived norms, roles, and values that organize scientific practice and institutions.

Table 1
Three Epistemic Foci in the Formation of Science Identity

Perception Target	Content	Related Identities
Self	Perception of one's science-related emotions and abilities, as well as resources and evaluations received from external sources	Personal identity
Society	Perception of the character of one's community, one's place within it, and the problems society is experiencing	Social identity
Science	Internalized meaning of what science is and the perceived norms, roles, and values that organize scientific practice and institutions	Situated identity

These three epistemic foci are illustrated in Table 1 and integrated into a conceptual model (Figure 1), which serves as the theoretical foundation of this study. From this perspective, science identity is not a singular or fixed label but the outcome of an ongoing process of positioning oneself within the scientific world, informed by how one perceives oneself, society, and science. Accordingly, this study defines science identity as self-awareness in the scientific context formed by synthesizing perceptions of these three dimensions (Figure 1).

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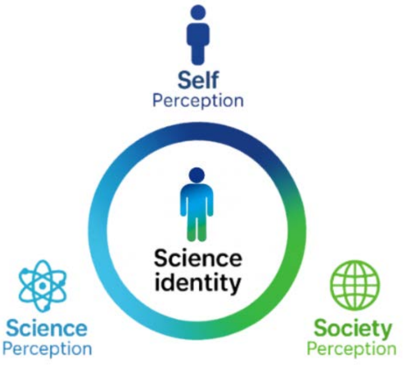
Figure 1
Science Identity Model



Given the limitations of examining such diverse aspects of identity in isolation, categorizing identity into distinct types can serve as a useful alternative. Such typologies enable learners to understand their own identities more clearly based on the defining features of each type. Moreover, attempts to typify science identity can contribute to identifying specific social practices and directions for participation in which learners can engage as "competent outsiders".

Despite the significance of science identity for lifelong engagement with science, most prior research has focused on elementary, middle, and high school students (e.g., Aschbacher et al., 2010; Kang, 2015; Vincent-Ruz & Schunn, 2018), whose identities are still in active formation. However, fewer studies have explored science identity among university students, who have completed formal science education and are at a critical juncture in consolidating their scientific orientations. Investigating identity types at this stage provides valuable insight into how science education shapes enduring identity trajectories and how different modes of identification emerge even after the completion of the national curriculum (Jiang & Wei, 2023).

Accordingly, taking university students as the study population, this research investigates science identity typologies as the final form after completion of the national science curriculum. Particularly, the aim is to expand the concept of science identity by moving beyond narrow, insider-centred definitions and acknowledging the various ways students relate to and engage with science.

Research Aim and Research Questions

Based on the framework above, the present study aims to examine the types of science identity that emerge among university students and to explore the defining characteristics of each type using Q methodology. In doing so, it expands the scope of science identity research beyond traditional insider models and contributes to a more nuanced understanding of how learners engage with science in everyday life. The research questions guiding this study are:

1. What types of science identities can be identified among university students?
2. What are the characteristics of each type of science identity?

Research Methodology

Design

In this study, science identity is conceptualized as a form of subjectivity—self-awareness situated within a scientific context. Because it involves an individual's metacognitive reflection on their own position in relation to science, society, and self, examining it requires an approach that allows participants to articulate and structure their personal perspectives in an autonomous and in-depth manner. Q methodology is well suited for this purpose, as it enables the systematic exploration of self-referential subjectivity and the identification of distinct patterns of perception (Kim, 2008). Moreover, this methodological choice reflects recent trends in science education research, where sociocultural framings are increasingly combined with psychological perspectives (Tytler & Ferguson, 2023).

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In line with this orientation, Q methodology reveals subjective perspectives while linking personal meaning-making to social and cultural contexts, thereby providing a nuanced lens on the multifaceted nature of science identity.

Q methodology analyzes participants' (P sample) subjective viewpoints by having them sort a set of statements (Q sample) according to their level of agreement. When the Q sample is constructed to reflect perceptions of "self", "society", and "science", the resulting Q-sorts capture integrated perceptions across these three epistemic dimensions, thereby representing participants' science identities. This integration allows for the identification of shared cognitive structures among participants and the classification of science identity types.

In the present study, the Q population was generated through a literature review, semi-structured interviews, and open-ended questionnaires, resulting in 335 self-referential statements about science identity. Following expert review, the statements were refined and categorized into the three dimensions ("self", "society", and "science"), and 42 representative statements were selected as the final Q sample.

The research was conducted within the context of Korean higher education and focused on university students who had completed the national science curriculum, thereby providing insights into science identity formation at the tertiary level. The study was conducted between June and September 2024, covering both data collection and analysis. Forty university students, recruited through purposive and snowball sampling to ensure diversity in both major and gender, participated in the Q-sorting process. For the sorting task, each participant received the Q cards and a quasi-normal distribution grid (–5 to +5) via postal mail, completed the sorting independently, and submitted their results through an online form. Participants first grouped the statements into agree, neutral, and disagree categories, then ranked them according to the degree of agreement on the provided grid. After completing the Q-sort, they provided written explanations for the statements they most agreed (+5) and most disagreed (–5) with. Follow-up interviews were conducted with participants who had the highest factor loadings in each type. The collected data were analyzed with PQMethod software using principal component analysis and varimax rotation, resulting in four distinct types of science identity.

Participants

The P sample denotes the set of participants who sort the Q statements. In Q methodology, it is generally recommended to have approximately 20 to 60 participants, following the principle of a small sample (Stephenson, 1953). This study conducted a Q-sorting with 40 university students and was approved by the Institutional Review Board of Korea National University of Education (2024-0176). For the selection of P samples, purposive sampling and snowball sampling were employed, considering the research subject and study purpose, while ensuring an appropriate distribution based on major field and gender. Detailed demographic information is presented in Table 2.

Table 2
Composition of the Participant Sample

Classification	Category	No. of People	Percentage (%)
Gender	Male	20	50
	Female	20	50
Science major status	Science major	16	40
	Other major	24	60

Development of the Q Sample

Table 3 presents the process of constructing the Q population and developing the Q sample to derive the types of science identity among university students. Here, Q population refers to the organized set of candidate statements, whereas Q sample denotes the representative subset used in the Q-sorting task.

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Table 3
Procedure for Developing the Q Sample

Stage	Procedure	Methods
Stage 1	Collection of Q population	A total of 335 Q statements were collected through literature analysis, in-depth interviews, and open-ended questionnaires related to "science identity".
Stage 2	Expert Review	Reviews were conducted by one science education expert, one Korean language education expert, and one Q methodology expert.
Stage 3	Selection of Q sample	A total of Q sample consisted of 42 statements were finalized, comprising 14 statements each in the categories of "self", "society", and "science" perception.
Stage 4	Reliability verification	Reliability was verified through two pilot tests conducted one week apart with two university students.

In this study, the Q population refers to all self-referential statements about science identity—one's identity in the context of science. The Q population was constructed through a literature review, in-depth semi-structured interviews, and open-ended online questionnaires. Specifically, 87 statements were extracted from research articles retrieved from RISS, DBpia, and Google Scholar using the keywords "science identity", "scientific attitude", and "scientific identity." In addition, 59 statements were derived from semi-structured interviews (30–50 minutes each) with three university students, and 189 statements were obtained from open-ended online questionnaires completed by 24 university students. Data collection continued until theoretical saturation was reached, resulting in a total of 335 statements comprising the Q population.

The Q sample—self-referential statements on science identity used for the Q-sorting task—was selected from the Q population through a three-step procedure. In Stage 1, 97 statements were retained after removing duplicates, clarifying ambiguous wording, and adjusting antonymous relationships. In Stage 2, the statements were categorized into the three recognition dimensions of "self", "society", and "science", and refined for style and difficulty. In Stage 3, the final set of Q sample consisting of 42 statements was confirmed through a validity review conducted by three science education experts. Subsequently, reliability was verified through two pilot tests conducted one week apart, yielding correlations of r ≥.70. The final Q sample is presented in Table 4.

Table 4
Q Sample

Classification	No.	Contents
"Self" perception	Q1	I am a person who is interested in and curious about natural phenomena.
	Q2	I am a person who feels a sense of reward in the process of acquiring new scientific knowledge.
	Q3	I am a person who has no fear or resistance toward learning science.
	Q4	I am a person who enjoys conducting science experiments.
	Q5	I am a person who enjoys science-related content (books, videos, etc.).
	Q6	I am a person who enjoys discussing science with others.
	Q7	I am a person with a basic level of scientific literacy.
	Q8	I am a person who easily understands scientific concepts.
	Q9	I am a person who performs experiments well by following scientific procedures.
	Q10	I am a person who has received sufficient material and emotional support related to science at home.
	Q11	I am a person who has received sufficient material and emotional support related to science at school.
	Q12	I am a person who has received sufficient material and emotional support related to science in the community and the nation.
	Q13	I am a person who appears to like science in the eyes of others.
	Q14	I am a person who appears to be good at science in the eyes of others.

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Classification	No.	Contents
"Society" perception	Q15	I am a person who plays a role in conducting scientific research in society.
	Q16	I am a person who plays a role in conveying scientific knowledge in society.
	Q17	I am a person who plays a role in learning science in society.
	Q18	I am a person who actually uses science and technology in society.
	Q19	I am a person who believes that gender, economic status, race, religion, and other factors influence the practice of science.
	Q20	I am a person who believes that a nation's scientific and technological status or level of education influences the practice of science.
	Q21	I am a person who usually perceives myself as a member of the Earth's ecosystem.
	Q22	I am a person who cares about environmental issues.
	Q23	I am a person who believes that environmental problems can be solved.
	Q24	I am a person who believes that the occurrence of environmental problems is related to the development of science and technology.
	Q25	I am a person who believes that science plays a role in solving environmental problems.
	Q26	I am a person who can make personal efforts in everyday life to solve environmental problems.
	Q27	I am a person who can cooperate and work together with others to solve environmental problems.
	Q28	I am a person who wants to monitor the actions of governments or companies to solve environmental problems.
"Science" perception	Q29	I am a person who believes that scientific knowledge can change at any time.
	Q30	I am a person who believes that scientific knowledge is accepted as valid only when it can be reverified.
	Q31	I am a person who thinks scientific knowledge is constructed through social consensus.
	Q32	I am a person who believes that science develops based on creativity and imagination.
	Q33	I am a person who thinks ethical attitudes are important in science.
	Q34	I am a person who believes that scientists possess extraordinary abilities different from my own.
	Q35	I am a person who believes that science develops through scientists even without my involvement.
	Q36	I am a person who has high confidence in science and scientists.
	Q37	I am a person who believes that I should learn science to broaden my career opportunities.
	Q38	I am a person who believes that I should learn science because the value of "knowing" itself is important.
	Q39	I am a person who believes that science dispels superstitious thinking and enables logical reasoning.
	Q40	I am a person who thinks science contributes to enriching my daily life.
	Q41	I am a person who thinks science contributes to the development of society.
	Q42	I am a person who believes that society can progress or regress depending on how science is used.

Q-sorting and Data Analysis

Q-sorting is the process by which the P sample (research participants) arranges Q sample statements according to their degree of agreement based on personal subjectivity. In this study, a non-face-to-face Q-sorting was conducted with 40 university students from July 1 to July 7, 2024. An arrangement board shaped as an 11-point quasi-normal distribution ranging from -5 to +5 (Figure 2) was used for the classification of Q sample. To operationalize the non-face-to-face procedure, each participant received the Q-card deck and the −5 to +5 quasi-normal grid by mail, completed the sort independently without consultation, and submitted the final placements via an online form.

Participants first read the Q samples and sorted them into three groups: agree, neutral, and disagree. They then ranked the statements within each group according to the degree of agreement and placed them on the arrangement board. For the two statements with the highest agreement (+5) and the two with the strongest disagreement (-5), participants provided written explanations in a post-questionnaire to gain deeper insight into their perspectives. After data analysis, follow-up interviews were conducted with the P sample showing the highest factor loading in each type.

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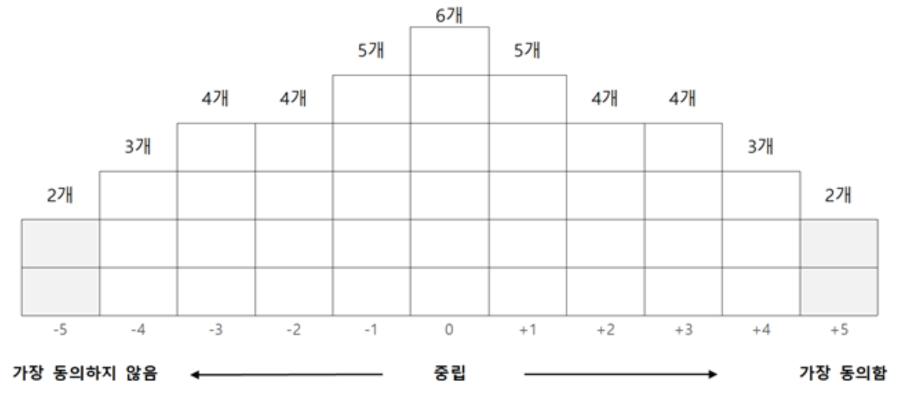
Figure 2
Q-sort Distribution Grid (11-point Scale)



The collected data were analyzed using PQMethod, an analytical tool for Q methodology. First, eight factors were extracted through principal component analysis to confirm that each factor's eigenvalue was ≥ 1.000. Then, after performing varimax rotation, the number of final factors was determined as four, considering significant loading values and cumulative explained variance.

Research Results

As a result of factor analysis using the PQMethod program, university students' science identity was derived into a total of four types. The eigenvalues for each type were 10.77 for Type 1, 4.40 for Type 2, 3.10 for Type 3, and 2.41 for Type 4, and the cumulative explained variance for the four factors was 51.73% (Table 5).

Table 5
Principal Component Analysis Results

Factors (Types)	Type 1	Type 2	Type 3	Type 4
Eigenvalues	10.77	4.40	3.10	2.41
Explained variance (%)	26.92	11.01	7.76	6.04
Cumulative explained variance (%)	26.92	37.93	45.69	51.73

The correlation coefficients between types were .4999 between Types 1 and 2, .1553 between Types 1 and 3, .5849 between Types 1 and 4, .3727 between Types 2 and 3, .2258 between Types 2 and 4, and .1578 between Types 3 and 4, indicating both similarities and differences among the types (Table 6).

Table 6
Inter-Factor Correlation Matrix

Factors (Types)	Type 1	Type 2	Type 3	Type 4
Type 1	1.000			
Type 2	.4999	1.000		
Type 3	.1553	.3727	1.000	
Type 4	.5849	.2258	.1578	1.000

The number of P samples significantly loaded on each factor was 14 for Type 1, 9 for Type 2, 7 for Type 3, and 4 for Type 4, with factor loadings presented in Table 7.

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Table 7
Factor Loadings by Type

	Type 1(N=14)			Type 2(N=9)			Type 3(N=7)			Type 4(N=4)		
1	P10	M/X	.7099	P11	M/X	.7242	P36	F/O	.6152	P39	F/O	.6127
2	P4	F/X	.7008	P27	M/O	.7239	P19	M/X	.5990	P8	M/X	.6125
3	P15	F/X	.6823	P9	F/X	.6780	P31	M/O	.5512	P35	M/O	.5828
4	P16	M/X	.6713	P12	M/X	.6148	P25	F/O	.5494	P23	M/X	.4149
5	P6	F/X	.6469	P26	M/O	.6031	P30	F/O	.4969			
6	P20	F/X	.6439	P14	M/X	.5972	P38	F/O	.4514			
7	P3	F/X	.6330	P32	M/O	.4750	P37	M/O	.4473			
8	P22	F/X	.6250	P40	M/O	.4353						
9	P5	F/X	.5405	P28	M/O	.3891						
10	P2	M/X	.5044									
11	P34	M/O	.5098									
12	P33	M/O	.4823									
13	P24	F/X	.4502									
14	P13	F/X	.4155									

* The symbols after the P sample represent gender (F: female, M: male) and science-related major (O: major, X: non-major), respectively

Type 1: Science Acceptance Type

There were 14 participants in Type 1, and the proportion of females and non-science majors was relatively high. Statements showing strong agreement or disagreement (standard score of ±1.00 or greater) identified by the P samples of Type 1 are presented in Table 8, and the distinguishing statements and their standard scores compared with other types are presented in Table 9.

Table 8
Strongly Agreed and Disagreed Statements and Their Z-Scores for Type 1

No.	Q statements	Standard Score
Q40	I am a person who thinks science contributes to enriching my daily life.	2.07
Q41	I am a person who thinks science contributes to the development of society.	2.02
Q24	I am a person who believes that the occurrence of environmental problems is related to the development of science and technology.	1.72*
Q42	I am a person who believes that society can progress or regress depending on how science is used.	1.54
Q33	I am a person who thinks ethical attitudes are important in science.	1.18
Q26	I am a person who can make personal efforts in everyday life to solve environmental problems.	1.03
Q8	I am a person who easily understands scientific concepts.	-1.09
Q3	I am a person who has no fear or resistance toward learning science.	-1.26
Q6	I am a person who enjoys discussing science with others.	-1.46
Q13	I am a person who appears to like science in the eyes of others.	-1.54
Q14	I am a person who appears to be good at science in the eyes of others.	-1.67
Q15	I am a person who plays a role in conducting scientific research in society.	-2.13*

Particularly significant distinguishing statements (p < .05) are indicated with an asterisk (*).

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Table 9
Distinguishing Statements with Z-Scores for Type 1

No.	Q statements	Standard Score
Q24	I am a person who believes that the occurrence of environmental problems is related to the development of science and technology.	1.72
Q16	I am a person who plays a role in conveying scientific knowledge in society.	0.14
Q31	I am a person who thinks scientific knowledge is constructed through social consensus.	0.13
Q17	I am a person who plays a role in learning science in society.	-0.54
Q15	I am a person who plays a role in conducting scientific research in society.	-2.13

Type 1 showed strong agreement with Q40 (z = 2.07), Q41 (z = 2.02), Q24 (z = 1.72), Q42 (z = 1.54), Q33 (z = 1.18), and Q26 (z = 1.03), in that order. In contrast, they strongly disagreed with Q15 (z = -2.13), Q14 (z = -1.67), Q13 (z = -1.54), Q6 (z = -1.46), Q3 (z = -1.26), and Q8 (z = -1.09). Type 1 participants were distinguished from other types by agreement statements Q24 (z = 1.72), Q16 (z = 0.14), and Q31 (z = 0.13), and by disagreement statements Q15 (z = -2.13) and Q17 (z = -0.54).

1) Perception of "self"

Type 1 participants exhibited negative perceptions of themselves in relation to science. They perceived themselves as individuals who did not easily understand scientific concepts (Q8), felt fear or resistance toward learning science (Q3), and had difficulty discussing science with others (Q6). They also believed that, from the perspective of others, they would not be perceived as someone who likes or excels in science (Q13, Q14).

> "I was confident and did well in social studies and language subjects, but science felt more difficult and intimidating, and my grades in science were lower than in other subjects." (P16)

In the post-questionnaire and interviews, participants repeatedly referred to school experiences in which they had perceived science as a difficult and even intimidating subject. Most, being from liberal arts backgrounds, appeared to have incorporated into their personal identity a negative self-awareness stemming from differences in academic achievement. Consequently, they viewed themselves as lacking both interest and aptitude in science, shaping a self-perception that was far removed from science.

2) Perception of "society"

Type 1 participants showed relatively high agreement with recognizing social issues related to science, such as environmental problems. They perceived science in connection with social challenges like environmental issues and positively evaluated the feasibility of engaging in environment-related actions at the individual level (Q24, Q26). On the other hand, they viewed themselves as being far from scientific research or production activities (Q15, Q17) and took a passive, marginal position regarding their role in society. Some agreed with the role of transferring scientific knowledge (Q16), but tended to separate themselves from core social roles.

> "I'm not a talented person who can make significant contributions to the development of science. I may not play a leading role in advancing science, but I am ready to accept and make use of it at any time." (P34)

As a result, Type 1 participants demonstrated high awareness of the connection between social problems and science, but formed a social perception that remained in the role of recipients or observers.

3) Perception of "science"

Type 1 participants had a deep awareness of the social and personal values of science, recognizing that science improves daily life and contributes to social development (Q40, Q41) as well as acknowledging its potential

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negative impacts, such as those arising from technological development (Q42). However, they maintained a sense of detachment, perceiving science as the exclusive domain of experts rather than an area where they could actively engage. Some participants tended to define their role as monitoring or critically accepting science, an attitude linked to valuing the ethical aspects of science (Q33) and the belief that science is shaped through social consensus (Q31).

> "I definitely know science is a great field, but it feels like a wall to me. Science seems like an area only people with special talents can do." (P4)
> "Even if non-scientists, including myself, are not involved, I think science can still develop. However, I am sceptical about whether it will develop in the right direction. I think… non-scientists, that is, those who will actually use science, should continue to monitor science and help it develop properly through incentives such as wealth and honor. … I think the reason we (non-scientists) learn science is to monitor the progress of science and technology." (P2)

In summary, Type 1 participants fully recognized the impact of science on individuals and society, regarded it as an expert domain, and tended to remain in the role of an ethical watchdog.

4) Characteristics of Science Identity

Type 1 participants maintained a certain distance from science based on self-awareness that they lacked interest or ability in it. Rather than recognizing themselves as subjects who directly explore or practice science, they tended to accept its values and social importance while taking a passive stance toward its influence. They acknowledged the social and environmental impacts of science and viewed their role as monitoring it. In other words, rather than directly contributing to science, they focused on the role of "external observers" who watch its social and ethical influence. As a result, Type 1 participants tended to accept and critically monitor its influence while maintaining a certain distance from science. Accordingly, this study labelled them as "science acceptance types".

Type 2: Science Use Type

There were 9 participants in Type 2, with a relatively high proportion of males, and science-related majors were evenly represented. Statements showing strong agreement or disagreement (standard score of ±1.00 or greater) identified by the P samples of Type 2 are presented in Table 10, and the distinguishing statements and their standard scores compared with other types are presented in Table 11.

Table 10
Strongly Agreed and Disagreed Statements and Their Z-Scores for Type 2

No.	Q statements	Standard Score
Q40	I am a person who thinks science contributes to enriching my daily life.	1.96
Q41	I am a person who thinks science contributes to the development of society.	1.71
Q32	I am a person who believes that science develops based on creativity and imagination.	1.49
Q42	I am a person who believes that society can progress or regress depending on how science is used.	1.47
Q29	I am a person who believes that scientific knowledge can change at any time.	1.30
Q35	I am a person who believes that science develops through scientists even without my involvement.	1.19
Q8	I am a person who easily understands scientific concepts.	-1.40
Q15	I am a person who plays a role in conducting scientific research in society.	-1.46
Q22	I am a person who cares about environmental issues.	-1.47*
Q23	I am a person who believes that environmental problems can be solved.	-1.50
Q16	I am a person who plays a role in conveying scientific knowledge in society.	-1.59
Q28	I am a person who wants to monitor the actions of governments or companies to solve environmental problems.	-2.04*

Particularly significant distinguishing statements (p < .05) are indicated with an asterisk (*).

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Table 11
Distinguishing Statements with Z-Scores for Type 2

No.	Q statements	Standard Score
Q10	I am a person who has received sufficient material and emotional support related to science at home.	1.04
Q11	I am a person who has received sufficient material and emotional support related to science at school.	0.64
Q33	I am a person who thinks ethical attitudes are important in science.	-0.02
Q22	I am a person who cares about environmental issues.	-1.47
Q28	I am a person who wants to monitor the actions of governments or companies to solve environmental problems.	-2.04

Type 2 showed strong agreement with Q40 (z = 1.96), Q41 (z = 1.71), Q32 (z = 1.49), Q42 (z = 1.47), Q29 (z = 1.30), and Q35 (z = 1.19), in that order. In contrast, they strongly disagreed with Q28 (z = -2.04), Q16 (z = -1.59), Q23 (z = -1.50), Q22 (z = -1.47), Q15 (z = -1.46), and Q8 (z = -1.40). Type 2 participants were distinguished from other types by agreement statements Q10 (z = 1.04), and Q11 (z = 0.64) and by disagreement statements Q28 (z = -2.04), Q22 (z = -1.47), and Q33 (z = -0.02).

1) Perception of "self"

Type 2 participants showed a neutral or negative perception of their internal capital, such as the ability to understand scientific concepts (Q8), even though they expressed a high level of agreement with statements indicating that they had been provided with sufficient material and emotional resources related to science at home and school (Q10, Q11). In both questionnaires and interviews, they did not define themselves as people with deep interest or affection for science, and they showed an attitude of accepting science only as much as necessary.

> "I know science is important, but I have never felt interested or affection in itself. At school, I thought it was just a subject to do, and I accepted experiments as a process to complete assignments." (P11)
> "I'm an efficiency seeker. I don't like to waste unnecessary time or energy, so I think it's better to learn as much as you need rather than delve into science or study." (P11)

In summary, Type 2 participants responded positively to the external support they received when recognizing "self," yet they formed a perception of self that valued efficiency and acknowledged having little affection for science.

2) Perception of "society"

Type 2 participants expressed indifference or held a pessimistic perception of "social problems". They showed little interest in environmental issues (Q22, Q23) and recognized themselves as people who were indifferent to the government's or corporations' efforts to address them (Q28). In questionnaires and interviews, it was notable that they tended to perceive environmental issues as external events unrelated to their own lives.

> "I don't think it's important unless it's an event closely related to my life, but I chose it because I'm not very interested in the environment and I'm even less interested in trying to solve it." (P32)

Their tendency was consistent in their perception of the role of science in society. Type 2 participants perceived themselves as peripheral beings in the exploration or delivery of scientific knowledge (Q15, Q16) and did not feel the will or necessity to participate in scientific activities. Although this may appear similar to Type 1, Type 2 is distinguished by their lack of intrinsic interest in science itself and low willingness to engage in scientific practice, rather than by a sense of distance caused by a lack of scientific ability.

> "I don't intend to participate in or research science in depth. There are many other things to pay attention to, and I don't see any reason to invest my time in science. They will do better." (P40)

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In summary, Type 2 participants were indifferent or sceptical toward science-related social issues, such as environmental problems, and developed a passive social perception in relation to science.

3) Perception of "science"

Type 2 participants showed high agreement on the social and personal values of science (Q40, Q41, Q42). This is similar to Type 1, but unlike Type 1, which viewed science with a sense of awe, Type 2 focused on external values and practicality, often emphasizing the practical utility of science by citing specific examples such as smartphones, medical technology, and robot vacuum cleaners.

> "Science, in my opinion, is about discovering new things or developing existing ones, but above all, finding the convenience and efficiency of our lives is the real power of science." (P26)

A relatively limited consideration of ethical issues related to science (Q33) was also a point of difference from Type 1. This ethical indifference appears to be reinforced by the belief (Q25) that science will be sufficiently developed by scientists even without their own direct participation. On the other hand, awareness of the nature of science—such as its creativity (Q32) and potential for change (Q29)—was high. This can be interpreted as the result of abundant support for external scientific resources (Q10, Q11) identified in the "self" perception, which contributed to the formation of broad scientific awareness.

In summary, Type 2 participants recognized science as a practical tool and paid attention to its external values, while forming a perception of science that was largely indifferent to its ethical aspects.

4) Characteristics of Science Identity

Type 2 participants valued the usefulness and benefits of science but lacked affection for or interest in science itself. While Type 1 formed a sense of distance from science through pessimistic self-awareness, Type 2 tended to distance themselves based on indifference. They were mainly concerned with issues that directly affected them and showed indifference to ethical issues or social responsibility. They viewed the development of science as the responsibility of scientists and recognized their own role as efficiently utilizing scientific outcomes. In other words, they perceived science as a means for personal convenience and social development, while showing a passive attitude toward in-depth inquiry or ethical reflection. They formed an identity as a "user" who maintains a distance from science yet makes use of its results, thus named the "science use type."

Type 3: Science-Loving Type

There were 7 participants in Type 3, with a balanced gender distribution and a relatively high proportion of science-related majors. Statements showing strong agreement or disagreement (standard score of ±1.00 or greater) identified by the P samples of Type 3 are presented in Table 12, and the distinguishing statements and their standard scores compared with other types are presented in Table 13.

Table 12
Strongly Agreed and Disagreed Statements and Their Z-Scores for Type 3

No.	Q statements	Standard Score
Q40	I am a person who thinks science contributes to enriching my daily life.	1.83
Q6	I am a person who enjoys discussing science with others.	1.78*
Q5	I am a person who enjoys science-related content (books, videos, etc.).	1.42*
Q42	I am a person who believes that society can progress or regress depending on how science is used.	1.36
Q17	I am a person who plays a role in learning science in society.	1.19
Q20	I am a person who believes that a nation's scientific and technological status or level of education influences the practice of science.	1.18

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No.	Q statements	Standard Score
Q36	I am a person who has high confidence in science and scientists.	-1.16*
Q9	I am a person who performs experiments well by following scientific procedures.	-1.40*
Q23	I am a person who believes that environmental problems can be solved.	-1.47
Q4	I am a person who enjoys conducting science experiments.	-1.48
Q34	I am a person who believes that scientists possess extraordinary abilities different from my own.	-1.53*
Q31	I am a person who thinks scientific knowledge is constructed through social consensus.	-1.64

Particularly significant distinguishing statements ($p < .05$) are indicated with an asterisk (*).

Table 13
Distinguishing Statements with Z-Scores for Type 3

No.	Q statements	Standard Score
Q6	I am a person who enjoys discussing science with others.	1.78
Q5	I am a person who enjoys science-related content (books, videos, etc.).	1.42
Q3	I am a person who has no fear or resistance toward learning science.	1.02
Q18	I am a person who actually uses science and technology in society.	0.99
Q7	I am a person with a basic level of scientific literacy.	0.87
Q13	I am a person who appears to like science in the eyes of others.	0.44
Q14	I am a person who appears to be good at science in the eyes of others.	0.04
Q32	I am a person who believes that science develops based on creativity and imagination.	0.02
Q36	I am a person who has high confidence in science and scientists.	-1.16
Q9	I am a person who performs experiments well by following scientific procedures.	-1.40
Q34	I am a person who believes that scientists possess extraordinary abilities different from my own.	-1.53

Type 3 showed strong agreement with Q40 ($z = 1.83$), Q6 ($z = 1.78$), Q5 ($z = 1.42$), Q42 ($z = 1.36$), Q17 ($z = 1.19$), and Q20 ($z = 1.18$), in that order. In contrast, they strongly disagreed with Q31 ($z = -1.64$), Q34 ($z = -1.53$), Q4 ($z = -1.48$), Q23 ($z = -1.47$), Q9 ($z = -1.40$), and Q36 ($z = -1.16$). Type 3 participants were distinguished from other types by agreement statements Q6 ($z = 1.78$), Q5 ($z = 1.42$), Q3 ($z = 1.02$), Q18 ($z = 0.99$), Q7 ($z = 0.87$), Q13 ($z = 0.44$), and Q14 ($z = 0.04$), and by disagreement statements Q34 ($z = -1.53$), Q9 ($z = -1.40$), Q36 ($z = -1.16$), and comparatively lower agreement with Q32 ($z = 0.02$).

1) Perception of "self"

Type 3 participants showed the only positive response among the four types in terms of perception of "self". They had no resistance to science (Q3), recognized themselves as having basic scientific knowledge (Q7), consumed scientific content (Q5), and expanded their knowledge through conversations about science with others (Q6). This may have contributed to being perceived by others as someone who likes and is good at science (Q13, Q14). On the other hand, their relatively low agreement with statements that they like or perform experiments well (Q4, Q9) indicates that affection for science does not necessarily translate into a preference for experimentation. In post-questionnaires and interviews, they expressed a strong sense of accomplishment in the process of learning and understanding science, showing high interest and affection toward the subject.

> "The process of learning and understanding new scientific knowledge feels very enjoyable. When I realize that the scientific knowledge I already had and the newly acquired information are closely connected, I feel very proud, as if I am gradually conquering the whole of science." (P37)

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In summary, Type 3 participants enjoyed learning and exploring science based on their affection and confidence in the subject. Through this, they expanded their knowledge and developed a self-perception as individuals who derive satisfaction from the process.

2) Perception of "society"

Type 3 participants recognized themselves in society as individuals who engage in learning and applying science (Q17, Q18). This stands in clear contrast to Types 1 and 2, who maintained a passive stance and distanced themselves from science. However, their sensitivity to broader social issues, such as environmental problems, was low, and they did not clearly perceive the connection between these issues and science (Q23).

> "Everything in our daily lives is connected to science, and I feel like I'm learning science in society and actually using it." (P36)
> "I like science, but I don't seem to connect well with social issues such as environmental issues." (P31)

In summary, although Type 3 participants showed relatively low awareness of science-related social issues such as environmental problems, they situated themselves within a scientific context and developed a perception of society that positioned them as active agents in learning and applying science.

3) Perception of "science"

Type 3 participants strongly agreed that science makes daily life convenient and influences society (Q40, Q42), a perception that was broadly similar to Types 1 and 2. However, unlike those types, they did not view science merely as a tool; instead, they attributed intrinsic value to it, grounded in interest and affection. Interview responses also revealed an attitude that recognized science as a channel for deeply understanding the world and as an element closely connected to daily life. In addition, they demonstrated a low psychological barrier to science, noting that they neither particularly idealized nor felt distant from scientists (Q34, Q36), and believed that anyone could become a scientist.

> "Everything around us is science. From the phones we use every day to the water we drink, there is nothing beyond science's reach. I see science not merely as a discipline but as an important factor shaping our lives. Learning science, to me, is a way to understand the world more deeply than simply acquiring knowledge." (P36)

In summary, Type 3 participants demonstrated affection and interest in science itself and strongly recognized its intrinsic value. They formed a perception of science that placed them on an equal footing with scientists and set a low entry barrier to scientific inquiry.

4) Characteristics of Science Identity

Type 3 participants showed deep affection and interest in science, positioning themselves within the scientific context. However, this affection did not extend to secondary dimensions of science. Their interest in social issues, such as environmental problems, was low, and their preference for experimental activities was also limited. This suggests a view of science primarily as an object of theoretical inquiry, with a focus on the intrinsic appeal of science itself rather than on social responsibility or ethical reflection. Consequently, the most salient feature of Type 3 participants was their strong affection for science itself. They were labelled the "science-loving type" because they formed an identity that pursues personal satisfaction and achievement, accepting science as an important part of life.

Type 4: Science Responsibility Type

There were 4 participants in Type 4, with both genders and science-related majors evenly represented. Statements showing strong agreement or disagreement (standard score of ±1.00 or greater) identified by the P samples of Type 4 are presented in Table 14, and the distinguishing statements and their standard scores compared with other types are presented in Table 15.

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Table 14
Strongly Agreed and Disagreed Statements and Their Z-Scores for Type 4

No.	Q statements	Standard Score
Q26	I am a person who can make personal efforts in everyday life to solve environmental problems.	1.88*
Q25	I am a person who believes that science plays a role in solving environmental problems.	1.71
Q23	I am a person who believes that environmental problems can be solved.	1.41*
Q22	I am a person who cares about environmental issues.	1.38
Q33	I am a person who thinks ethical attitudes are important in science.	1.38
Q41	I am a person who thinks science contributes to the development of society.	1.22
Q37	I am a person who believes that I should learn science to broaden my career opportunities.	-1.15
Q4	I am a person who enjoys conducting science experiments.	-1.35
Q6	I am a person who enjoys discussing science with others.	-1.39
Q31	I am a person who thinks scientific knowledge is constructed through social consensus.	-1.48
Q14	I am a person who appears to be good at science in the eyes of others.	-1.80
Q16	I am a person who plays a role in conveying scientific knowledge in society.	-1.85

Particularly significant distinguishing statements ($p < .05$) are indicated with an asterisk (*).

Table 15
Distinguishing Statements with Z-Scores for Type 4

No.	Q statements	Standard Score
Q26	I am a person who can make personal efforts in everyday life to solve environmental problems.	1.88
Q23	I am a person who believes that environmental problems can be solved.	1.41
Q40	I am a person who thinks science contributes to enriching my daily life.	0.13
Q2	I am a person who feels a sense of reward in the process of acquiring new scientific knowledge.	-0.96

Type 4 showed strong agreement with Q26 (z = 1.88), Q25 (z = 1.71), Q23 (z = 1.41), Q22 (z = 1.38), Q33 (z = 1.38), and Q41 (z = 1.22), in that order. In contrast, they strongly disagreed with Q16 (z = -1.85), Q14 (z = -1.80), Q31 (z = -1.48), Q6 (z = -1.39), Q4 (z = -1.35), and Q37 (z = -1.15). Type 4 participants were distinguished from other types by agreement statements Q26 (z = 1.88) and Q23 (z = 1.41), and by disagreement with Q2 (z = -0.96) and comparatively lower agreement with Q40 (z = 0.13).

1) Perception of "self"

Type 4 participants showed generally negative responses in their perception of "self". They recognized themselves as people with little interest or sense of reward in learning science (Q2) and as being reluctant to experiment or talk about science (Q4, Q6). However, unlike Type 1, this was not a self-deprecating attitude but rather a calm acceptance that science was not their area of interest. They also recognized that they would not be seen as someone good at science (Q14) and showed an attitude of placing little significance on this perception.

> "I don't think I ever thought it was fun when learning science. I studied because I had to take a test, and other than that, I never became interested in science first." (P8)
> "I don't know what I'll look like to others, and I don't want to look like either, so I disagree the most." (P39)

In summary, Type 4 participants were largely uninterested in science in their self-perception, tended not to care much about how others saw them, and formed a personal identity as people distant from science.

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2) Perception of "society"

Type 4 participants showed very high awareness of "social problems". In particular, they expressed deep interest in environmental issues (Q22) and recognized these in connection with science (Q25). Some participants cited interest in and willingness to address environmental problems as a key motivation for choosing their major, and they were also engaged in personal practices under the belief that science could serve as a means of solving social problems (Q23, Q26). However, regarding scientific roles, they tended to limit their perception to research activities and did not consider their own practices as scientific acts (Q16).

> *"The reason I came to engineering school, in the process of choosing a department, my motivation is "environment". The department was selected with the aim of creating and using polymers for the environment." (P39)*
> "It will make a new polymer, which will help with waste disposal problems that are thrown into the environment, and make replacements with environmentally beneficial substances such as biodegradation." (P39)

In summary, Type 4 participants were deeply concerned with the environment and sustainable development. They were strongly motivated to independently engage in solving environmental problems but demonstrated a social perception that involved only a limited awareness of their broader scientific role.

3) Perception of "science"

Type 4 participants valued the contribution of science to social development and environmental problem-solving (Q41). However, they expressed lower agreement with the personal value of science (Q40, Q37) and tended to view it primarily as a resource for addressing public problems. This perspective was accompanied by high expectations for the ethics and social responsibility of scientific research (Q33) and a belief that science should work for the benefit of society.

> "The biggest role of science is to solve the greatest problem we face: the environmental problem. I think it is time for everyone in the world to focus on solving environmental problems. That is why environmental problems are serious and urgent to be solved." (P8)

In summary, Type 4 participants emphasized the social value of science, particularly its role in addressing environmental issues, and formed a science perception that located science within a social and ethical context.

4) Characteristics of Science Identity

Type 4 participants did not have particular affection or interest in science, but they highly valued its social role in addressing environmental issues. For them, science was viewed more as a means of solving public problems than as a tool for personal achievement or everyday convenience. Although they had a strong willingness to engage in environmental protection, they did not associate their actions with science because they primarily understood scientific practice as limited to academic research. Consequently, Type 4 participants focused more on the societal and environmental impacts of science than on science itself. This perspective led to their categorization as the "science responsibility type", reflecting an orientation toward science within a social and ethical context.

Discussion

This study identified four distinct types of science identity among university students—science acceptance, science use, science loving, and science responsibility—which together illustrate the multifaceted ways individuals relate to science after completing formal schooling. These types expand the conceptualization of science identity beyond insider-oriented definitions and highlight diverse forms of meaningful engagement with science. Below, we discuss the characteristics of each type, their educational implications, and the broader social roles participants can play.

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Type 1: Science Acceptance Type – Ethical Observers with Distanced Engagement

The "science acceptance type" reflects the general attitude of modern people who perceive science as an external element (Sturgis & Allum, 2004). They tended to position themselves as monitors who did not consider themselves scientific insiders but instead made ethical judgments about the impact of science on society, which aligns with Irwin's (2002) extended concept of scientific participation. Furthermore, their tendency to view science as a domain of expertise and fixed ability, excluding themselves from it, corresponds with Dweck's (2006) concept of a fixed mindset, suggesting that negative learning experiences during school years may influence later scientific self-awareness.

Pedagogical support for this group should focus on reducing psychological distance from science and fostering a stronger sense of agency. Strategies include cultivating a growth mindset, engaging students in socio-scientific issue discussions, and incorporating case-based learning around environmental or technological ethics. Such approaches can help transform passive recognition of science into more active forms of participation (Sadler, 2004; Zeidler & Nichols, 2009).

Participants of the science acceptance type may also contribute as democratic citizens by critically monitoring the social and ethical implications of scientific development. For instance, they can help steer science toward more equitable and sustainable directions by responding to issues such as inequality or environmental harm, or by joining public debates that demand transparency and accountability in decision-making (Irwin, 2002).

Type 2: Science Use Type – Instrumental Consumers with Limited Reflexivity

The "science use type" perceives science primarily as a practical tool, emphasizing external benefits and everyday applications. This orientation aligns with Vision II of scientific literacy, which highlights the capacity to apply science in daily life (Roberts, 2007). However, their indifference to social responsibility and ethical dimensions reflects the concerns of Weinstein (2008) and Irwin (2002) that a purely instrumental view of science may weaken critical participation and reduce science to mere technical achievement.

Educationally, this group benefits from approaches that bridge Vision II and Vision III—fostering not only practical application but also ethical responsibility and sustainability. Case-based learning on topics such as environmental issues or technology ethics (Archer et al., 2015) can help broaden their perspective from consumption to critical awareness of science's wider implications.

As democratic citizens, participants of this type can extend their engagement beyond personal benefit by contributing feedback from their experiences, mediating between science and society, and helping to improve technologies, disseminate practical values, and strengthen the reciprocal relationship between science and society.

Type 3: Science Loving Type – Intrinsically Motivated Explorers

The "science-loving type" is characterized by strong intrinsic motivation and affection for science, valuing it for its inherent interest rather than as a tool for utility or problem-solving. This aligns with self-determination theory (Deci & Ryan, 2013), which identifies intrinsic motivation as a key driver of sustained learning and exploration. Such learners often view scientists as relatable figures, increasing the likelihood of pursuing science-related careers (Hazari et al., 2010; Harackiewicz et al., 2002).

However, their focus on personal enjoyment does not always extend to issues of social responsibility or ethical engagement, resembling Carlone and Johnson's (2007) "research scientist identity" rather than an altruistic orientation. Educational support should therefore both nurture their intrinsic curiosity—through inquiry-based and individualized pathways—and expand it toward broader contexts, such as project-based learning on community issues or ethical debates.

Science-loving participants can immerse themselves in exploration based on their passion for science and take practical roles in sharing it with others. They may lead in creating scientific knowledge, approaching social problems scientifically, and contributing as science communicators who can readily convey scientific thinking.

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Type 4: Science Responsibility Type – Socially Conscious, Practically Active

The "science-responsibility type" values science primarily as a tool for ethical and social responsibility, especially in tackling environmental challenges. Their orientation resembles Carlone and Johnson's (2007) altruistic scientist identity, yet they often do not view their actions as part of a scientific role. Closely aligned with Vision III of scientific literacy, they emphasize sustainability and civic responsibility, showing that even with limited confidence in their scientific ability, learners can still engage meaningfully in socio-scientific problem solving (Rickinson, 2001).

Educationally, this group benefits from approaches such as problem-based learning on issues like environmental protection, sustainability, or bioethics, which combine inquiry with ethical reflection. Socio-scientific issue frameworks can also help learners practice decision-making in contexts of moral and social complexity. Such experiences encourage them to integrate science with civic participation, extending scientific literacy into democratic action.

Participants in this type can actively address science-related social issues, such as environmental problems, by situating science in a social and ethical context. They can take on the role of democratic citizens who use science as a means of social change, emphasizing its moral standards and contributing to public discourse for sustainable development.

The four types of science identity identified in this study can all be understood as diverse potential realizations of Feinstein's (2011) notion of the competent outsider. A competent outsider refers to a citizen who, without becoming a scientist, possesses the capacity to engage with and interpret science in ways that are relevant to their own life (Feinstein et al., 2013; Osborne & Allchin, 2024). This represents a significant conceptual shift beyond the traditional "insider" orientation of science education. Moreover, each identity type embodies a distinct facet of scientific citizenship Irwin (2001): the science acceptance type functions as a critical monitor of science's societal impact; the science use type acts as a mediator who shares the practical value of science and technology; the science loving type serves as a disseminator who promotes the enjoyment and diffusion of scientific knowledge; and the science responsibility type engages science as a means of addressing social problems and advancing sustainability. Together, these identities provide a foundation for citizens' diverse modes of participation in science-related policies and discourses within democratic societies.

Accordingly, the four types of science identity presented here demonstrate that the aims of science education cannot be confined to the training of future scientists. Each type illustrates a distinct pathway for practicing scientific literacy as democratic citizens, and science education should seek to strengthen their respective strengths, address their weaknesses, and support learners in performing meaningful social roles from their own positions.

Conclusion and Implications

This study classified and analyzed the science identity of university students who had completed the national-level curriculum. The conclusions are as follows.

First, the science identity of university students was categorized into four types using the Q methodology. Based on a reconceptualized science identity framework, 42 Q-statements were selected, and Q-sorting was conducted with 40 university students. The collected data were analyzed through principal component analysis and varimax rotation using the PQMethod program. As a result, four distinct types of science identity were identified and named the *science acceptance type*, *science use type*, *science-loving type*, and *science responsibility type*.

Second, the characteristics of each science identity type differed. The *science acceptance type* recognizes the importance and both social and personal value of science but perceives itself as being distant from science, maintaining the stance of an ethical watchdog rather than an active inquirer. The *science use type* perceives science as a practical tool, employing it for personal convenience and social development, yet tends to show indifference toward ethical considerations or social responsibility. The *science-loving type* enjoys inquiry and learning based on a deep affection for science, valuing its intrinsic worth, but shows a weaker connection to social responsibility or environmental issues. The *science responsibility type* approaches science from the perspective of social responsibility rather than personal interest, placing particular emphasis on the role of science in addressing environmental problems and exhibiting a practical attitude toward such issues.

By revealing various aspects of science identity, the study suggests that even those who are not "insiders" majoring in or professionally practising science can engage with science as "competent outsiders", developing their own unique relationships with it and participating meaningfully in scientific activities within their respective spheres. However, given the limited scope of the sample and the presence of cases that could not be clearly

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assigned to a single type, caution should be exercised when generalizing the results. In particular, because the sample was drawn from a single national context (South Korea), the findings may not generalize to settings with different curricula or sociocultural conditions. The relatively small number of participants, and especially the low representation in Type 4, may also reduce the stability and robustness of this type's interpretation. These limitations indicate that some of the identified characteristics could be context-specific and may not capture the full diversity of science identities observed in other educational or cultural settings. As such, the results should be interpreted as exploratory rather than definitive, and as providing a foundation for further comparative research.

Future research should therefore combine both quantitative and qualitative approaches with learners of varying ages and backgrounds, or adopt longitudinal designs to analyze the process of identity change over time. In addition, cross-national replications in settings with differing curricula and sociocultural conditions would help test the typology's cross-contextual robustness and generalizability. Furthermore, it will be important to define concrete forms of scientific practice that are feasible at the learner or competent outsider level, and to design educational programs that integrate these elements.

Conflict of Interest

The author(s) declared no conflicts of interest.

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